REVIEW AND RECOMMENDATIONS for the INTERAGENCY SHIP STRUCTURE COMMITTEE'S FISCAL 1980 RESEARCH PROGRAM.

A Report Prepared by the SHIP RESEARCH COMMITTEE of the Maritime Transportation Research Board Commission on Sociotechnical Systems National Research Council

National Academy of Sciences
Washington, D.C.
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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the Committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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This report was prepared for the interagency Ship Structure Committee, consisting of representatives from the Military Sealift Command, the U.S. Coast Guard, the Naval Sea Systems Command, the Maritime Administration, the American Bureau of Shipping, and the U.S. Geological Survey, and is submitted to the Commandant, U.S. Coast Guard, under provisions of Contract DOT-CG-80356-A between the National Academy of Sciences and the Commandant, U.S. Coast Guard, acting for the Ship Structure Committee.

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ABSTRACT

The Ship Research Committee (SRC) of the National Research Council provides technical services covering program recommendations, proposal evaluations and project advice to the interagency Ship Structure Committee (SSC), composed of representatives from the U.S. Coast Guard, the Naval Sea Systems Command, the Military Sealift Command, the Maritime Administration, the American Bureau of Shipping and the U.S. Geological Survey. This arrangement requires continuing interaction among the SRC, the SSC, the contracting agency and the project investigators to assure an effective program to improve ship hull structures through an extension of knowledge of materials, fabrication methods, static and dynamic loading and response, and methods of analysis and design. This report contains the Ship Research Committee's recommended research program for five years, FY 1979-1983, with 11 specific prospectuses for FY 1980. Also included is a brief review of 24 active and 12 recently completed projects.

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The SHIP STRUCTURE SUBCOMMITTEE acts for the Ship Structure Committee on technical matters by providing technical coordination for the determination of goals and objectives of the program, and by evaluating and interpreting the results in terms of ship structural design, construction, and operation.

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INTRODUCTION

Organizational and Administrative Matters

Establishment of Committees

Since 1946, the National Research Council's Ship Research Committee (SRC) and its predecessors have been rendering technical services to the interagency Ship Structure Committee (SSC) in developing a continuing research program, sponsored by the SSC and funded collectively by its member agencies, to determine how ship structures can be improved for greater safety and better performance without adverse economic effect.

The SSC was established in 1946 upon recommendation of a Board of Investigation, convened by order of the Secretary of the Navy, to inquire into the design and methods of construction of welded steel merchant vessels. As that investigation was brought to a close, several unfinished studies and a list of worthy items for future investigation remained. The Board recommended that a continuing organization be established to formulate and coordinate research in matters pertaining to ship structure. The chart, Figure 1, which follows, shows the relationship

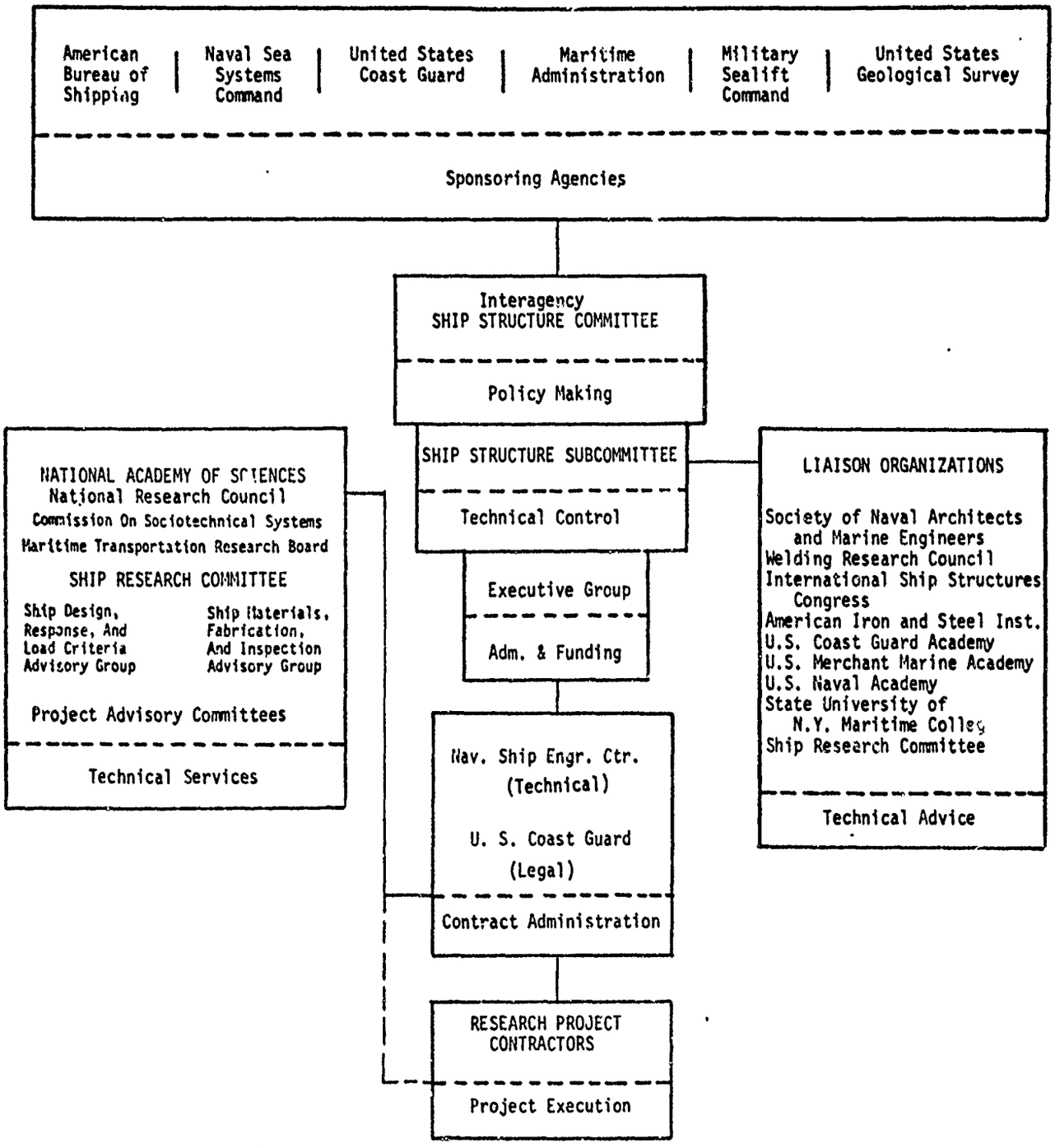

FIG. 1. - SHIP STRUCTURE COMMITTEE ORGANIZATION CHART

of the various organizational entities involved in the work of the SSC.

Committee Composition and Responsibilities

The SSC is composed of senior officials, one each, from the U.S. Coast Guard, the Naval Sea Systems Command, the Military Sealift Command, the Maritime Administration, the American Bureau of Shipping and the U.S. Geological Survey.

The SSC formulates policy and approves program plans, and provides financial support through its member agencies for the research program.

Four representatives from different divisions within each agency meet periodically, as a Ship Structure Subcommittee (SSSC) to assure achievement of program goals and to evaluate the results of research projects in terms of ship structural design, construction and operation.

Members of the SRC and its advisory groups are selected for their competence, experience and expertise in relevant areas from academic, governmental and industrial sources. The members serve as individuals contributing personal knowledge and judgement and not as representatives of organizations in which they are employed or with which they may be associated. The SRC's responsibilities to the SSC are to assist in setting technical objectives; define research projects; recommend research priorities; evaluate proposals; review the active projects, including progress

and final reports, and prepare summaries of related research work.

In order to respond to the needs of the USGS, which became a participating agency of the SSC this past year, additional members, active in or knowledgeable about the design of offshore structures, were appointed to the SRC and each of its Advisory Groups.

Research Program Development

It has become standard procedure to have an annual joint meeting of members of the SRC, the SSSC and the Hull Structure Committee of the Society of Naval Architects and Marine Engineers (SNAME) to review current research needs and suggestions for future research projects. Each agency of the SSC prepares a memorandum describing its discernment of needed research. These memoranda are provided to all participants in advance of the meeting.

At the 1978 meeting, a new format was instituted aimed at enabling an exchange of ideas regarding research needs among the agencies represented. These discussions did produce, in varying degrees, expressions of commonality of each agency's interests in the research needs. Seven panels were set up, one for each goal in the five-year plan, with an individual representative from each agency assigned to each panel. The panels met in a round-table discussion led off by a member of the SRC. The panel sessions were held consecutively so that all other participants could observe and join the discussion as appropriate. A few weeks later,

a meeting of the SRC, SSC, and SSSC was held at which the SRC presented its preliminary reactions to the inputs from the joint meeting and indicated project areas for which prospectuses could probably be developed.

Project Development

The suggestions contained in these memoranda, those brought out at the joint meetings, those generated within the SRC and its Advisory Groups and those obtained from other sources are carefully studied for applicability to the SSC research program in terms of need, immediacy, program continuity and likelihood of successful and meaningful completion. A prospectus is drafted by the appropriate SRC Advisory Group for each of the research projects that is considered worthy of SSC support. These are reviewed and ranked by the SRC and included in an annual report to the SSC. The SSC determines which projects will be supported. The prospectus becomes a part of the Request for Proposal (RFP) and subsequently a part of the contract document. The RFP's are prepared and issued through the cooperative effort of the Naval Ship Engineering Center, which provides technical contract administrative support services, and the USCG, which handles the actual business of contracting. The RFP's go to research laboratories, universities, shipyards, and other organizations and are advertised in the Commerce Business Daily.

Proposal Evaluation Procedure

Any organization interested in doing work submits a proposal and an estimated cost. The USCG Contracting Office removes the cost data and transmits the technical data in the proposal to the SRC for technical evaluation and review.

The SRC Executive Secretary verifies that no SRC or Advisory Group member or affiliated company is represented in the proposals. This important step avoids conflict of interest. The SRC chairman selects an ad hoc proposal evaluation committee that generally consists of the Chairmen of the SRC and the pertinent advisory group, two or three other members from either the advisory group or the SRC, the Secretary of the SSC, the Contract Officer's representative and frequently one or two SSC liaison members.

The proposals are evaluated for the analysis of the problem, the proposed solution, the assessment of the scope of the effort and the adequacy of the organization and personnel.

After the evaluation committee judges the technical merit of the proposals, ranks them, and comments on any shortcomings, the USCG Contracting Officer forwards the technical evaluation and cost data to the SSC. The SSC considers the proposals together with the technical evaluation and costs, and sends its recommendations to the Contracting Officer, who, following routine procurement practices, then awards a contract.

Annual Report Summary

SRC-SSC research activities during the current year are covered in an annual report by status and progress reports on active and pending projects and synoptic reports on research projects that have been or probably will be completed during the current year. The annual report also includes the SRC recommendations to the SSC for continued and new research to be funded during the ensuing fiscal year.

This, the latest in the series of annual reports, covers research activities during fiscal year 1979, sets forth recommendations for the SSC's fiscal year 1980 research program and outlines a five-year research planning program.

Five-Year Research Program Plan Development

A continuing program of research in marine structures must be guided by a perception of the directions in which marine activity is moving. There can be no doubt that marine-oriented activity is and will continue to increase in response to the expanding demands of society for energy and materials. The past decade has seen a great change in the character of ships. The trend toward specialized ship types is one aspect of the change; for example, economies resulting from large size have produced half-million deadweight-ton tankers. This size trend is seen also in Great Lakes bulk carriers and liquified natural gas (LNG) ships. Size has increased rather than diminished

the criticality of loads and structural and material responses. The need to be able to predict accurately the nature, occurrance and magnitude of loads and responses is concommittantly greater.

New concepts on the drawing boards; for example, those associated with the offshore thermal energy conversion (OTEC) platforms, will continue to challenge the designer with structures of increasing size and complexity. Furthermore, as the need to explore and exploit the resources of arctic regions and northern continental shelves increases, the designers of ships and marine structures will have to be able to deal confidently with the harsh environmental conditions associated with these areas. Data on waves, ice conditions, currents and the computational and modelling techniques to translate such data into loads are far from complete. While these and other like considerations are not new, the urgency of the need for precise and realistic load assessment in terms of occurrence, duration, frequency and magnitude is more pressing.

These considerations will surely be debated and placed in perspective in the course of the development of a 20-year plan for research in marine structures now in progress.

The FY-1980 program and the associated 5-year plan are aimed at producing developments that will support the emerging needs of marine development as best they can now be

perceived. Some of the specific areas addressed in the program are discussed in the following paragraphs.

Vibration

The joint SSC-SNAME Vibration Symposium held in October, 1978, produced eighteen excellent papers covering the field of ship vibration and noise from the standpoints of the researcher, the designer, the shipbuilder and the owner and crew. The proceedings were published by SNAME and a critique of the symposium has been prepared by E. Scott Dillon. This material will be used for future project planning in ship vibration research.

The SSC work on propeller-induced vibration received a preliminary unveiling at the vibration symposium in the form of a rather detailed approach to the analysis of propeller-induced vibration in ship design. The question of future research in this field will be taken up after this project's results and those from the symposium are reviewed.

A question the SSC should begin considering is how far to go in supporting research into propeller-induced vibratory loads. This is a field in which the Navy at its David Taylor Naval Ship Research and Development Center and others, notably the Davidson Laboratory at Stevens Institute of Technology, have done a great deal of work. And, it apparently continues under Navy and MARAD support. It is suggested that there may be good reason for the SSC to concentrate on structural vibratory response and not get too deeply involved in wake and propeller interaction in

connection with prediction of propeller-induced vibratory loads. This and, in fact, the whole matter of propeller vibration research might well be a subject for consideration by an ad hoc group, or possibly it could be reviewed in the course of the development of the long-range structural research plan.

The response of the hull girder in springing and the vibration associated with slamming depends strongly on the various damping characteristics. Hydrodynamic damping and added mass have been extensively modelled but the effect of forward speed is as yet not completely accounted for. Structural and cargo damping are also involved and, while these are believed to be less important than hydrodynamic damping, little has been done to quantify their contributions.

In addition to wave bending moments and those induced by springing and slamming, there is a class of loads that are static or quasi-static in nature. These include thermal loads, still-water bending moment (SWBM) and the ship's induced wave bending moment. Realistic evaluation of the strength of a ship requires that the magnitude and time phasing of these loads be accounted for. The correlation between full-scale stress data and logbook information with respect to SWBM is poor. Because SWBM is basic to even first-order approximations of total bending moment, a means of estimating SWBM, possibly probabalistically, and relating it to cargo-loading patterns is needed.

Arctic Requirements

Investigations of ice loads have been, and continue to be, carried out by the USCG and MARAD. The results should provide a base for the development of improved ice-strengthening criteria. These, at present, are arbitrary and do not relate ice-strengthening requirements to expected ice conditions and the resulting loads.

To support the expected expansion of marine activity into arctic regions, a look at steels used in non-marine cold-weather applications to see what might be commercially available and used in arctic marine applications, considering fracture toughness, thickness range, stress levels and temperature ranges is an economical first step.

As new designs and the technical needs of new structures introduce new materials, new problems are anticipated. It is true that no steels or alloys are developed solely for ship construction, but there are abundant technical data for those metals in commercial use. However, ship construction and operation impose different types of loading and service from those experienced in other applications, therefore there may be a need for study in some particular facet of the use of these steels. For instance, the number of repetitions of stress in the life of a ship on the North Atlantic may be very high, requiring an understanding of the high-cycle fatigue behavior of steels in a moderately corrosive environment. Likewise, alloys for

use at cryogenic temperatures are coming into broader use for liquified gas carriers suggesting the need to study fatigue of structures constructed of these materials.

Fatigue

Long-term corrosion fatigue is potentially an important consideration in the design of offshore drilling platforms. Designers of these platforms need 50-year high-cycle corrosion fatigue data in sea-water environments that will support a long-term design life. Because of the long experimental times necessary to develop 10^7 to 10^9 cycle data, extrapolation techniques will be required.

During the past decade, several projects have been conducted relating to the fatigue of ship structures. Ship response to sea motions continues to be studied using computer simulations and actual measurements on instrumented SL-7 containerships. The fatigue behavior of ship steels, weldments and fabricated details also continues to be studied in a variety of programs. Further progress in the analysis of fatigue behavior requires a coupling of ship response to sea motions with the materials response to cyclic loads. Such a coupling is the fatigue-loads spectrum.

Each ship has a unique spectrum that is a function of response characteristics, the trade route (reflected in time spent in each sea state), and the probable speed, heading and cargo loading while in each sea state. Given the fatigue-loads spectrum, a stress spectrum applicable to

a given location and joint detail can be calculated using a transfer function determined by finite-element analysis of the ship structure. The stress spectrum and fatigue data on ship steels can be analyzed using cumulative damage and crack-growth models to assess the anticipated fatigue behavior of the particular location.

Conceptually, a fatigue-load spectrum can be developed for each ship and trade route, and stresses at locations of interest, fatigue-control spots, can be determined to derive stress spectra for the fatigue analysis. Work now in progress should show how close this concept is to reality and indicate the direction future work should take.

Fracture

The rate of loading, or strain rate, is an important parameter in determining the fracture toughness of a ship structure at a given temperature. Strain rates experienced in the hull girders of ships caused by wave bending, springing and slamming have been estimated and inferred, but little actual measured data are available. This information is needed to establish the correlation between laboratory fracture-toughness tests and material performance in ships.

Fracture criteria remains a field that resists satisfactory quantification, yet it is a basic consideration in design. Because notch toughness is an expensive characteristic to provide, the designer needs a meaningful

measure of notch toughness that he can relate to actual structures, loads and operating temperatures. In-depth evaluation of fracture criteria for ships and marine structures therefore needs to be continued.

A bothersome phenomenon that occurs in laboratory tests of some steels is cleavage "pop-in." "Pop-in" is a localized rapid crack propagation or burst that is arrested short of full fracture. It is often considered the failure point even though the load increases beyond the point of pop-in before complete failure. This behavior contributes to data scatter and may result in undue conservatism in the application of fracture-toughness criteria.

Collision, Stranding and Drydocking

A survey of actual ship collisions has produced virtually no useful data to verify theoretical models of the phenomenon. The USCG has a comprehensive plan for research in this field, including model and full-scale tests. This work will be followed with new initiatives proposed by the SRC to assist or supplement the work as it progresses.

While encounters with extreme or "episodic" waves occur infrequently, the results are always disasterous. And, in the case of large tankers, pose such a threat to the environment that an understanding of these occurrences is clearly important. Surveying the history of damage by large waves and identifying the locations and conditions under which they occur may suggest if research needs to be done. It is likely that designing a ship structure rugged enough

to withstand such waves would be impractical. In any case, means for predicting the occurrence, location and duration of exteme waves is required for purposes of avoidance.

The stranding and loss of the ARCO MERCHANT off Cape Cod and the AMOCO CADIZ off the French coast highlighted the desire of the USCG for development of a model and computer program to aid in assessing the damaged stability and strength of a stranded ship and in estimating the loads on it. This is a complex problem and a general solution may prove impractical. However, the value of such a tool to help in making on-scene decisions about off loading, refloating, etc., makes even a partial solution attractive. This work was originally recommended in a single FY-1979 prospectus that included drydocking as well. In the course of the program review by the SSC, it was decided to create two separate projects, one, a computer-aided procedure for ship grounding calculations, and the other a computer-aided procedure for drydocking calculations.

Verification

While the results from a project to correlate computed and measured primary hull bending stresses for the SL-7 containerships showed reasonably good agreement, the change in hull shape above and below the still waterline, not accounted for in existing methods, turned out to be important and had to be approximated arbitrarily. It now appears feasible to study means of treating this nonlinear

problem of shape change. A further opportunity to verify theory and computational methods by comparison with measured data will be afforded by work now underway by the USCG aboard the Great Lakes bulk carrier M/V S.J. CORT. The full-scale measurements of stress, pressure and wave conditions will be compared with measurements in model scale as well as with calculated values.

Five-Year Research Program Plan

The five-year research planning program in Table I builds upon current activities and places them in perspective with contemplated work in various project areas during the next four years. The project areas are classified under the following seven goals of the SSC:

Advanced Concepts and Long-Range Planning
Loads Criteria
Response Criteria
Materials Criteria
Fabrication Techniques
Determination of Success/Failure Criteria (Reliability)
Design Methods

Work in each of these areas includes adequate verification procedures to assure that sound recommendations are made. The thrust is to expand the existing base of knowledge in each area that will result in design methods, fabrication procedures and materials for safer and more efficient ships.

It is intended that the program be dynamic and flexible in that it can be modified and redirected to be responsive to changing circumstances.

TABLE I

SHIP RESEARCH COMMITTEE'S RECOMMENDATIONS FOR CONTINUING FIVE-YEAR FISCAL RESEARCH PLANNING PROGRAM FOR THE SHIP STRUCTURE COMMITTEE.

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
GOAL: I - ADVANCED CONCEPTS AND LONG-RANGE PLANNING					
Overall research planning studies	Conduct joint meeting to develop Agencies' & Societies' present and planned research work.	→	→	→	→
	Examine current marine structural research status (all agencies). Develop an overall outline to accomplish general objectives. Five Year Plan.	→	→	→	→
	Initiate project to develop a coordinated plan including specific proposed technical approaches for each section; provide detailed references to past & existing work both domestic & foreign, & provide cost estimates & a cost-benefit ratio. (SR-1259)*	Conduct workshops to gain additional input & priorities to the coordinated plan. (SR-1259)*	←	(Commence following research plan.) →	
Conduct Technical Symposium	Conduct joint SSC-SNAME Vibration Symposium.	Review Vibration Symposium Results & Recommendations	Begin preparations for 1982 Symposium	Conduct Symposium on Arctic Marine Technology	Review Arctic Symposium Results

* (SR-1259) designation refers to projects described in the yellow pages of this report.

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
	GOAL: I - ADVANCED CONCEPTS AND LONG-RANGE PLANNING (CONT.)				
Advanced Materials & Applications: Concrete	Initiate a survey of construction & operating experience of marine concrete structures. Develop the basis for a research program to provide guidance & recommendations to designers & builders of floating structures. (SR-1270).	Complete SR-1270 & evaluate recommendations for follow-on research.	Begin research, e.g., an understanding of the fatigue requirements & performance of large concrete ship structures.	Continue specific research as indicated by previous work.	
Materials Trade-Off	Review SR-1222, "Materials Trade-Off Study", results.	Develop a work plan for material trade-off and qualification studies for high-performance marine structures.	Initiate important projects.	Continue effort.	Consider program in composite materials.
Collisions and Groundings	Develop grounding loads & analysis computer program. (SR-1272).	Develop prospectus for model simulation of groundings according to various scenarios & associated model experiments.	Investigate the common technologies and engineering analysis applicable to both ship collision and grounding problems.	Investigate interim design proposals to limit grounding damage.	Develop generalized design criteria for groundings.
	Review SR-1237 evaluation of low-energy collision damage theories & design methods.	Develop prospectus for model simulations of low-energy ship collision dynamics for various collision scenarios and associated model experiments.	Develop & perform full-scale or model tests to verify computer simulations & to establish important collision phenomena.	Complete test program. Compare & modify collision stranding theory.	Develop generalized design criteria for low-energy collisions & energy absorption criteria & parametric studies for various structural configurations.
				Develop analytical procedures for low-energy collision & grounding including studies by ship type.	Consider requirements for inspection after low-energy collision and grounding.

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
	GOAL: I - ADVANCED CONCEPTS AND LONG-RANGE PLANNING (CONT.)				
Collisions and Groundings (Cont.)	Complete & evaluate SR-1246 ship collisions & groundings survey on research studies.	Maintain an awareness of the USCG-MARAD full-scale ship collision test program development.			
	GOAL: II - LOADS CRITERIA				
Static/Quasi Static, Thermal, (Diurnal, Cryogenic, Hot) Cargo, Ballast, Fuel, Cargo Distribution, Light Weight of Ship, Ship's Induced Wave, Ice, Impact, Crushing.	Begin project to review literature, ship operations, & ice histories of navigable waterways for ice loadings on ships. Compare with present ice strengthening of ships. Indicate where additional information required. (SR-1267)	Review ice project results & develop plan to obtain necessary data.	Carry out ice loading plan.		
	Complete project SR-1227 to compile and analyze several loading variables for three different types of ships.	Develop program to obtain static/quasi static data for typical ships. (80- 9)*	Begin program to obtain static/quasi static data for typical ships.	Complete data collection program.	Prepare Design Load Profiles. Recommend modifications to Design Criteria.
Dynamic Cargo Liquid, Sloshing, Dry, Shifting Load, Pumping Problems, Mobile Cargo (Wheeled Vehicles)	Review the SR-1251 results to survey test, analyze, and develop liquid dynamic load criteria in slack cargo tanks for LNG carriers.	Review & correlate current model & full-scale non LNG liquid slosh data. Conduct model tests to complete correlations for varjous fill depth, geometry, & excitation parameters. (80-11)	Complete 80-11	Evaluate significance of impulsive slosh loads in full-scale liquid tanks. Develop prediction of wall response to impulsive slosh pressure. Recommend design criteria for tank walls.	Develop general purpose curves & tables for use in design of liquid cargo tanks.

* (80-9) designation refers to projects recommended in the green pages of this report.

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
		GOAL: II - LOADS CRITERIA (CONT.)			
Dynamic Cargo, etc. (Cont.)			Review & categorize types of shifting cargo loads, & establish priority of dynamic load problems. Develop plan for analysis of high-priority items.	Conduct analyses and/or tests to establish dynamic loads & corresponding structural responses to shifting cargo under typical operational conditions.	Develop curves & tables for ready use in design for dynamic loads due to shifting cargo.
Propeller-Induced Vibrations	Complete SR-1240 to survey and evaluate present methods to predict propeller-induced vibration in hull structural elements, including skewed propellers.	Review SR-1240 results.	Identify & describe existing analytical methods for predicting wake fields.	Develop wake field studies.	Review results of wake field studies.
			Identify & describe analytical methods for predicting magnitude & nature of propeller cavitation. Develop program, and conduct tests to validate cavitation study results.	Evaluate cavitation studies and produce guide.	
			Consider effects from propeller emergence.	Develop test plan to measure propeller emergence effects.	Initiate test plan to measure propeller emergence effects.

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
		GOAL: II - LOADS CRITERIA (CONT.)			
Wave-Induced Wave Records/Spectra, Local Ship Wave Instrumentation Slamming, Green Water Steady State.	Prepare a position paper for SSC defining needs of ship and ocean platform designers for wave data and proposing ways in which SSC might promote and facilitate its acquisition, analysis, and dissemination.	Review status of wave data collection and prospects for application in design.	Collect & analyze wave information and develop long-term wave statistics necessary for fatigue failure analysis.	Continue collection and analysis of wave information.	Develop a method to statistically estimate the combined wave-induced bending and torsional loads necessary to perform structural failure analysis.
		Review USCG Great Lakes project utilizing portion of full-scale slam instrumentation package.	Develop prospectus for full-scale slam instrumentation and wavemeter data collection.	Analysis of impact pressure and velocity. Correlate trials data with model experiments and theory.	Develop technology to predict impact loads for ship design consideration.
				Conduct full-scale slamming, bow-flare and green water impact trials to collect data using the instrumentation developed under previous SSC project.	
		Develop a motions and distributed loads program accounting for hull shape above the still-water line. (80-1)	Continue 80-1.		
		Survey and analyze experience of vessels encountering extreme waves. (80-6)	Review 80-6 results.		

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
		GOAL: III - RESPONSE CRITERIA			
Vibrations Analysis & Prediction, Steady State (Springing, Bending, Torsion). Transient, (Whipping), Measurement/ Verification.		Collect & evaluate ship structural damping data (SR-1261).	Review SR-1261 and indicate test program to verify design extensions.	Initiate program to verify design extensions.	Examine design extension verification results.
Stress/Deformation Analysis & Prediction, Measurement/Verification, Steady State, Transient, Static, Thermal.	Instrument *CORT* for full-scale pressure measurements. (SR-1275).	Obtain SR-1275 data.	Evaluate SR-1275 results.		
	Initiate pressure distribution model tests in waves to determine pressure loads (SR-1271).	Complete pressure distribution model tests. Use ABS computer program to calculate pressure distribution corresponding to model tests.	Evaluate model, full-scale, and computer results for pressure distribution.		
	Continue collection and reduction of SL-7 scratch-gage data. (SR-1215 and SR-1245). Evaluate data & develop criteria to remove gages. (SR-1268)	Continue SL-7 scratch-gage data collection. (SR-1215 and SR-1245). Review SR-1268 results.	Continue scratch-gage extreme stress data collection on SL-7, if necessary, or gather data on ships of another class.	Continue scratch-gage extreme stress data collection.	Continue scratch-gage extreme stress data collection.
	Verification of calculated stress as compared to full-scale measured values. (SR-1235).	Evaluate SL-7 Research Program Results (80-3)			
	Establish deflection criteria for ship in relation to main machinery alignment tolerances. (SR-1266)	Complete the SR-1266 study.	Fabricate and test large-scale models or instrument actual ship hull elements to verify criteria.	Examine large-scale hull element test results.	

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
		GOAL: IV - MATERIALS CRITERIA			
Arctic Materials		Institute program to survey material property data for applications in Arctic conditions. (80-4)	Review results and include new materials into other on-going material property studies.	Make presentation at Arctic Marine Technology Symposium.	
Offshore Platform Materials		Begin a survey of fracture control plans which include materials, properties and designs for increased reliability in hostile marine environments. (80-5)	Use data to indicate research in needed areas.		
Fracture and Fatigue Control	Explain observed fatigue behavior in terms of measured load spectra developed from ship strain measurements. (SR-1254). Evaluate available procedures for evaluation and selection of fabricated structural details under cyclic-loading conditions. Classify the vulnerability of ship details under cyclic loading using the best available procedure. (SR-1257).	Conduct experimental work to verify the classification procedure selected in the previous work. Conduct experimental work to classify the vulnerability of details whose behavior is not known. (SR-1257).	Develop fatigue criteria & design procedure in the selection of ship details. Include effects of weld geometry and residual stresses.	Evaluate fatigue criteria and design procedure.	
		Initiate a program to use long-term corrosion fatigue data in the design of offshore structures and ships. (80-2)	Continue 80-2	Review program and recommend needed research.	Provide an initial guide for a fatigue control plan in offshore structures.

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
		GOAL: IV - MATERIALS CRITERIA (CONT.)			
Fracture and Fatigue Control. (Cont.)	Review ABS-Battelle's fatigue program on Great Lakes Bulk Carrier.				
	Complete fracture toughness characterisation of HAZ'S in ship steel weldments. (SR-1238)	Initiate program to conduct research in area of elastic-plastic fracture. (80-7).	Continue to gather information from studies. Apply results to actual application experience.	Develop elastic-plastic fracture design methodology.	
	Evaluate fracture criteria for ship steels and weldments from information developed in recent SSC projects. (SR-1265).	Consider recommendations from SR-1265 and evaluate fracture arrests concepts for ship steels.			
Corrosion Control	Start a survey and life cycle cost study to identify the most economical corrosion control systems in the existing and projected economic and regulatory climate. (SR-1269).	Decide, on the basis of cost study results, whether or not a more rational approach to corrosion margins is required.	Initiate study or experimental program.	Make recommendations for rule and/or design method changes.	
		GOAL: V - FABRICATION TECHNIQUES			
Improved Weld Quality Guides	Complete a survey of existing non-destructive inspection (NDT) methods and adapt them to underwater use. (SR-1243).				

TABLE I

GOAL: V - FABRICATION TECHNIQUES (CONT.)

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
Improved Weld Quality Guides (Cont.)	Complete the survey and evaluation of secondary structural welds such as for webs and longitudinals and determine if additional inspection guidelines are needed. (SR-1249).				
	Review NDI practices used for heavy section castings, forgings and weldments. Prepare an interpretive report of the procedures and acceptance limits applicable to ship components. (SR-1255).	Review SR-1255 results.			
	Review MARAD work on weld quality levels for structural integrity in ships.				
	Review work on distortion control in aluminum weldments.	Initiate program to develop a guide to minimize distortion in aluminum weldments. (80-10).	Publish the guide.		
			Initiate program to develop weld quality standards in aluminum welds in ships.	Publish aluminum weld quality standard report.	

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
		GOAL: V - FABRICATION TECHNIQUES (CONT.)			
Welding Design Requirements	Complete update on allowable fillet weld sizes and determine whether research work is needed. (SR-1248).	Review needs for additional fillet weld testing. Maintain awareness of ABS pursuits in this area.	Develop additional information for allowable fillet weld sizes.	Provide recommendation for allowable fillet weld sizes.	
	Review design guidelines, welding procedures and testing methods to prevent lamellar tearing in ship steels. (SR-1250).				
Effects of High-Deposition Welds-Improved HAZ Properties	Complete worldwide literature survey and continue to evaluate weld procedure and metallurgical control for adequate toughness in the HAZ of weldments when using high-deposition rate processes. (SR-1256). Consider using test methods developed in SR-1238 to evaluate welding procedures.	Identify critical controls in the development of improved weldments using a variety of high-deposition rate processes and procedures. (SR-1256).	Determine whether new materials and/or processes provide adequate service life using fracture and fatigue tests.	Provide an initial guide for use on high-deposition rate weld processes in ship construction.	
	Continue to monitor MARAD's program on improved ship steels.				
Structural Details	Examine different sound and failed structural details in 36 ships. (SR-1258).	Complete survey on 36 additional ships. (SR-1258).	Review and combine previous project results into a design and fabrication manual.	Review safety analysis of ship structural details against fracture and fatigue failures. Develop reliability based inspection and maintenance schedules to insure safety against brittle fracture.	Develop an overall fracture-control plan for ship structures that incorporates both fatigue and fracture behavior of fabricated ship details and a reliability analysis.

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
		GOAL: VI - DETERMINATION OF SUCCESS/FAILURE CRITERIA (RELIABILITY)			
Failure Modes and Safety Analyses	Review of available techniques for safety analyses. (SR-1241).	Analyses and assessment of major uncertainties in current ship hull design. (80-8).	Evaluate reliability in terms of failure probability or safety index for major failure moves for specific types of ship design according to current requirements.	Formulate risk-related or probability-based criteria for design of ship hulls against specific modes of failure; this may include (a) ships of conventional (steel) material; (b) ships of future marine material, e.g., composites.	Undertake analysis of past structural failure of ships to support reliability analysis of ship hull safety.
		GOAL: VII - DESIGN METHODS			
Design Procedures Efficiency, Economics, Optimization, Test and Evaluation, Preliminary Design.	Review report on evaluating effect of varying ship proportions and hull materials on hull flexibility. (SR-1239).				
	Complete SR-1261 to determine the ultimate strength of a ship hull girder.	Review procedure for determining ultimate strength under combined vertical, lateral, torsional loads. (SR-1262).	Develop procedure for predicting transverse plane motions and transverse and torsional loads.	Fabricate large-scale hull girder model and test to failure, measuring stresses and deformations and comparing with calculations.	Evaluate possibility of using ultimate strength in hull girder design roles.
		Review existing optimization techniques and develop a computer program for preliminary design. (SR-1274)	Verify the preliminary design program.	Develop preliminary design procedures for ends of ship to avoid vibration and slamming damage.	Verify the preliminary design procedures for ends of ships.

TABLE I

PROJECT AREA	FY 1979	FY 1980	FY 1981	FY 1982	FY 1983
		GOAL: VII - DESIGN METHODS (CONT.)			
Design Procedures (Cont.)	Continue supplementary monograph to *SHIP STRUCTURAL DESIGN CONCEPTS* (SR-1263).	Complete SR-1263 monograph.			
	Develop dry docking analysis program. (SR-1273).	Complete and review dry-docking program results.			

ADVANCED METHOD FOR SHIP-MOTION AND WAVE-LOAD PREDICTIONS

SRC Priority 1

Long-Range Goal: Loads Criteria

BACKGROUND

The phenomena of bow-flare impact, slamming and the shipping of water on deck are not adequately handled by existing linearized ship motion theory, which assumes that motions are small and that the ship is "wall-sided" above and below the still waterline. Model test results have exhibited a nonlinear relationship between wave loads and wave heights. This nonlinear phenomenon may result in part from changes in hull form shapes above and below the still waterline for large relative motions between ship and wave.

Previous attempts to account for hull form shape above the still waterline, such as SSC-231, Further Studies of Computer Simulation of Slamming and Other Wave-Induced Vibratory Structural Loadings on Ships in Waves have exploited various aspects of strip theory but have yielded only the resultant load on each section. In order to adequately predict distributed hydrodynamic pressure loads on the instantaneous wetted surface, a closer look at the flow at the affected sections is required. Account should be taken of the actual hydrodynamics, including the exact body boundary condition. The breakdown of the free surface into spray sheets is difficult to handle numerically and does not constitute the most serious aspect of the loading. Hence some form of linearization of the free surface

MAN-HOURS

First Year	-	2000 (approved June 2, 1977)
Second Year	-	3000 (approved June 6, 1978)
Third Year	-	3000

SR-1256, "INVESTIGATION OF STEELS FOR IMPROVED WELDABILITY IN SHIP CONSTRUCTION" SRC Priority 0

Long-Range Goal: Fabrication Techniques

BACKGROUND

Domestically, experimental work on electroslag and electrogas welding for marine applications has identified the need for an improved ship hull steel that would have minimal tendencies for degradation of the heat-affected-zone (HAZ) and weld-metal properties. Related work is directed toward preserving HAZ toughness in steels for service temperatures to approximately -50°C. Weldments that use higher deposition rate welding practices in low-sulfur and sulfide-shape-controlled plate steels are being evaluated. The SSC now has an on-going three-year project to investigate the additional metallurgical control that appears necessary for minimizing degradation of HAZ and weld-metal properties. Since only two years of work have been authorized, additional funding and authorization are required to continue the work through the third year.

OBJECTIVE

The objective of this study is to examine the metallurgical factors affecting the weldability of steels and to select the optimum materials and welding parameters to provide improved resistance to degradation of the heat-affected-zone properties in weldments made with high-deposition rate processes.

MAN-HOURS

First Year	-	2000 (approved June 2, 1977)
Second Year	-	3000 (approved June 6, 1978)
Third Year	-	3000

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SRC Priority 1

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boundary condition on the actual body shape may be acceptable. The importance of viscosity depends on the section shape and the mode of motion. Except for computational stability, viscous effects should not be particularly important for finite vertical motions of typical ship sections. Lateral motions, however, may involve significant vortex formation and a large increase in damping.

There are a number of numerical procedures potentially capable of analyzing the distributed load in the time domain (Ref. 1). Hydrodynamic finite-element methods offer the greatest flexibility but require large amounts of machine time and sophistication of the user. A two-dimensional numerical method has been proposed by Chapman (Ref. 2). The body boundary condition is solved exactly and the linearized free surface is represented by a spectrum of wave potentials. A procedure such as this could be coupled with the lumped parameter methods described in SSC-231 (Ref. 3) to provide estimates of large amplitude motions and distributed loads. Note that any other appropriate method proposed by the contractor will be considered.

OBJECTIVE

The objective of the study is to develop a method and appropriate computer program for predicting ship motions and the distributed wave loads accounting for the hull form shape above and below the still waterline.

WORK SCOPE

The following phases are considered essential to meet the objective:

PHASE I: Model Formulation

Formulate the hydrodynamic model and the calculation procedure, clearly defining the likely range of applicability of the method.

PHASE II: Computer Program

1. Develop a computer program and test it against selected theoretical and experimental models. The program should be designed to facilitate movement to a different computer system.

2. Provide a user's manual including a test case and a list of all machine dependent coding and options.

REFERENCES

1. Chapman, R.: "Survey of Numerical Solutions for Ship Free-Surface Problems," Proceeding of Second International Conference on Numerical Ship Hydrodynamics, University of California, Berkeley, September 1977.

2. Chapman, R.: "Large Amplitude Transient Motion of Two-Dimensional Floating Bodies," Journal of Ship Research, to be published in Spring, 1979.

3. Kaplan, P. and Sargent, T.P.: Further Studies of Computer Simulation of Slamming and Other Wave-Induced Vibratory Structural Loadings on Ships in Waves, Ship Structure Committee Report SSC-231, 1972.

MAN HOURS

First year Phase I: 1500

Second year Phase II: 2500

LONG-TERM CORROSION FATIGUE OF WELDED MARINE STEELS — SRC Priority 2

Long-Range Goal: Materials Criteria

BACKGROUND

A prominent feature of the offshore environment is the cyclic loading imposed on structures by wave action, with the result that corrosion fatigue is a failure mode which must be considered by designers. This has long been recognized in the design of ships, offshore oil drilling platforms, and other marine structures of welded steel. The principal impact has been a restraint on effective use of high-strength steels, and the imposition of fracture-control plans involving design details, redundant structures, enhanced notch toughness, and inspection. Particular attention must be paid to welded joints and to local stress concentration factors.

However, as designers of offshore platforms move from familiar Gulf of Mexico applications to deeper water and harsher environments, they find that fatigue calculations for 20 to 50 years design life (with a suitable safety factor) depend strongly on fatigue data in the range of 10^7 to 10^9 cycles to failure, particularly data obtained from large welded specimens with realistic sea-water environment, cyclic-loading rate, and temperature control. Such data are very scarce, with most data over 10^7 cycles coming from accelerated tests of small specimens. Various

interpretations and extrapolations of available data lead to order of magnitude differences in calculated fatigue life.

Research in this area should improve reliability and cost effectiveness of a wide variety of marine structures--including deepwater ports, offshore energy systems, floating vessels, risers, ocean mining, artificial islands, communications, navigation, aquaculture, and seafloor facilities, as well as fixed platforms.

OBJECTIVE

The objective of the proposed research is to define and evaluate currently available technology for assessing the long-life corrosion fatigue behavior of welded joints in sea water; and to develop a plan for long-term future efforts, if required.

WORK SCOPE

The following tasks are considered essential in meeting the objective:

a) Review current literature, and synthesize these data into a statement of current knowledge in the objective area. Particular emphasis shall be placed on obtaining and digesting data from the massive UK-ECSC Offshore Steels Research Project, as well as the recent review of corrosion fatigue of tubular joints by Battelle, and continuing API-sponsored work.

b) Identify one or more candidate design/analysis procedures, for example, crack initiation and propagation using a fracture mechanics approach.

c) Check each procedure against the available test data for realistic welded joints used to project the behavior of prototype structures in the marine environment.

d) Thoroughly investigate, from the standpoint of reliability, sensitivity of such projections to inherent data variability, different interpretations, and various parameters which must be assumed or supplied by the analyst.

e) Analyze existing vessels or marine structures having long or otherwise significant service histories to further calibrate or validate the proposed design procedures.

f) Develop a long-term plan in detail. This plan shall describe the types of tests needed, how the data will be applied to design, and how its reliability will be established. Estimates of time, cost, and benefits shall also be made.

MAN-HOURS

First Year - 2000

Second Year - 2000

SL-7 PROGRAM SUMMARY, CONCLUSIONS AND RECOMMENDATIONS — SRC Priority 3

Long-Range Goal: Response Criteria

BACKGROUND

The Ship Structure Committee was presented with the opportunity in 1971 to cooperate with the American Bureau of Shipping and Sea-Land Service, Inc., in a program of instrumentation, data collection and data analysis on a class of modern high-speed containerships, the S.S. SEA-LAND MCLEAN, and Class. A less comprehensive study was carried out on the S.S. BOSTON in a previous SSC research program directed toward the accumulation of full-scale seaways-induced loading data.

The goal of the program has been to advance understanding of the performance of ships' hull structures and the effectiveness of the analytical and experimental methods used in their design. While the experiments and analyses of the program were keyed to the SL-7 containership and a considerable body of data were developed relating specifically to that ship, the conclusions of the program are completely general, and thus applicable to any surface ship structure. The program included measurement of hull stresses, accelerations and environmental and operating data on the S.S. SEA-LAND MCLEAN, development and installation of a microwave radar wavemeter for measuring the seaway encountered by the vessel, a wave-tank model study and a theoretical hydrodynamic analysis which relate to the wave-

induced loads, a structural-model study and a finite-element structural analysis which relate to the structural response, and installation of long-term stress recorders on each of the eight vessels of the class.

Results of each of the program elements have been or will be published as Ship Structure Committee reports and each of the reports relating to this program will be identified by an SL-designation along with the usual SSC-number. With the exception of continuing scratch-gage measurements, the instrumentation and data analysis program is complete.

OBJECTIVE

The objective of this study is to conduct a general review and evaluation of the plans, procedures, results and accomplishments of the SL-7 program.

WORK SCOPE

The following tasks are considered essential to the study:

(1) Review all SL-7 reports, as published by SSC, NTIS, SNAME and the University of California, Berkeley.

(2) Summarize and evaluate the SL-7 program with respect to the following topics:

a) Ship motion measurement and prediction

b) Load measurement and prediction

c) Stress measurement and prediction

d) Determination of strain rates

e) Methods of statistical evaluation of data

(3) Interview all program sponsors to obtain their respective evaluations of program goals and accomplishments.

(4) Recommend further analysis of program results for future applications.

MAN-HOURS

1000.

STEELS FOR MARINE STRUCTURES IN ARCTIC ENVIRONMENTS — SRC Priority 4

Long-Range Goal: Materials Criteria

BACKGROUND

The development of resources in arctic regions will soon require marine structures capable of withstanding combinations of very low temperature, high stress and fatigue. For such structures to be designed with some degree of confidence, reliable information on materials and environment is required.

OBJECTIVE

The objective is to evaluate research reports and other literature on material selection, fabrication techniques and material reliability on non-marine cold-weather applications as to the usefulness of these materials and techniques for marine structures in an arctic environment.

WORK SCOPE

The following topics should be considered while conducting the review and evaluation:

1. The temperature range which a marine structure must withstand, within the areas where such structures might be erected.
2. The mechanical properties of a series of candidate steels to be used within this temperature range, with particular emphasis on fracture toughness and fatigue.

3. The maximum thickness of steel that can be employed in welded structures at the design temperature.
4. The mechanical properties of weld metal that can be used with candidate steels at the design temperature.
5. The fracture criteria that should be used for such structures.
6. The combinations of steels, welding rods and thickness for marine structures in arctic environments and temperature limits within which each combination can be used.
7. Identify the need for improved materials and welding procedures for arctic marine applications.

MAN-HOURS

1500

FRACTURE CONTROL FOR OFFSHORE STRUCTURES SRC Priority 5

Long-Range Goal: Materials Criteria

BACKGROUND

A fracture-control plan may be defined as a plan by which design options, materials selection, fabrication control, and inspection procedures are integrated into a consistent strategy, with the goal of preventing failure by fracture in service of welded structures.

In the case of fixed offshore platforms, this goal is achieved through the use of redundant structure, the selection of materials with enhanced notch toughness and improved through-thickness properties for critical locations, fabrication quality control, and in-service inspection. To a large extent, these measures fall in the domain of customary practice, with some attendant variation from company to company, and from region to region.

OBJECTIVE

The objective of this study is to produce a summary of the technology and practices that constitute the fracture-control plans used by designers, builders and operators of offshore structures.

WORK SCOPE

The following tasks are considered essential in summarizing the fracture-control plans:

a) Contact knowledgeable designers, fabricators, and operators of offshore structures for

descriptions of their current fracture-control practices.

b) Review pertinent U.S. and foreign literature.

c) Identify the essential elements of a fracture-control plan.

d) Identify areas where existing technology would suggest cost-effective improvements in current practice.

e) Identify areas where further research is needed.

MAN-HOURS

1500

SHIP STRUCTURE LOADING IN EXTREME WAVES SRC Priority 6

Long-Range Goal: Loads Criteria

BACKGROUND

Numerous ships have been severely damaged or lost through structural failure caused by encounter with an episodic wave of extreme height and force. There is need of better understanding of the behavior of ships hull structures under such conditions. Research is underway on the ultimate strength of ships structural elements under collapse loads. However, there is now no understanding of how these extreme waves load the ship's structure. It is important to know whether the critical problem is one of hull girder failure, extreme bow slamming, "green water" on deck, superstructure damage, or some other phenomenon.

OBJECTIVE

The objective is to understand the possibility of a ship encountering some kinds of extreme waves and to understand the significance of this in ship structural design.

WORK SCOPE

The following tasks are to be considered in meeting the objective:

1. Survey published data world-wide about these occurrences.
2. Consult classification societies, marine insurers and salvors, owners, government

agencies and any other sources of unpublished data on these losses.

3. Classify the data gathered by geographical location, incident environmental conditions, type vessel, type damage, loss of life, financial loss, and environmental damage.
4. Identify the most common and the most severe forms of structural failure which have occurred in the past from extreme wave loading.
5. Analyze and discuss the data to determine the most significant circumstances surrounding these cases.
6. Recommend a program of future research.

MAN-HOURS

1000.

DISCONTINUOUS (POP-IN) FRACTURE IN SHIP STEELS — SRC Priority 7

Long-Range Goal: Materials Criteria

BACKGROUND

Ship steels generally exhibit elastic-plastic fracture behavior for the temperature and loading rates encountered in service, i.e. through-thickness yielding precedes fracture. During fracture toughness testing, the typical load-displacement record for such a steel exhibits large displacements prior to reaching a maximum load. Sometimes, however, the rising load curve is interrupted by pop-in due to cleavage. This is particularly true as thickness and loading rate are increased and temperature decreased. The arrest of the cleavage crack in a fracture toughness test is facilitated by the load drop that accompanies pop-in. Since a drop in load cannot be relied on in service, fracture toughness testing criteria generally consider the load displacement at pop-in as the failure point. However, for some cases (e.g. weldments or thick plates) the pop-in may be a very local event and treating it as the failure condition results in undue conservatism and contributes to scatter in the test data.

OBJECTIVE

The objective is to develop an understanding of the cleavage pop-in phenomenon in carbon-manganese steels.

WORK SCOPE

A systematic series of fracture-toughness tests should be conducted on ABS grade steel at a constant loading rate and temperature within the ductile-to-brittle transition range. The test temperature should be selected on the basis of preliminary tests which indicate the temperature where cleavage pop-ins are likely to occur. The tests should be conducted under nominally identical conditions of temperature, loading rate, and test material. Specimen configurations (e.g. bend and tensile), specimen dimensions, load train compliance, and material characteristics should be systematically varied. In each test the specimen should be unloaded immediately after pop-in and the extent of cleavage marked by heat tinting or other suitable methods. The variation in the extent of cleavage should then be evaluated in terms of the fracture mechanics parameters at pop-in, specimen orientation, specimen type and dimensions, and load-train compliance. Efforts should be made to develop a theoretical model to predict the extent of cleavage pop-in.

MAN-HOURS

First Year - 1500

Second Year - 2000

ANALYSIS AND ASSESSMENT OF MAJOR UNCERTAINTIES IN SHIP HULL DESIGN

SRC Priority 8

Long-Range Goal: Reliability

BACKGROUND

The safety of structures in general, and ship hull structures in particular, is a matter of acceptable risk. In order to properly consider safety from this standpoint, safety may be measured in terms of the probability of no failure, or conversely, the probability of failure.

Some probability of failure is invariably unavoidable in engineering design, in view of the fact that designs are almost never developed with complete technical information; i.e. designs are formulated under conditions of uncertainty. Also, there are economic considerations. There is uncertainty in the predicted maximum load that a ship may experience over its life; similarly, there is uncertainty in the estimation of the resistance of a ship, in any given mode.

Probabilistic methods of safety analysis and probability-based design methods are now widely available in other areas of engineering, including civil structural engineering, and nuclear power plant engineering, among others. The key element in the implementation of any existing probabilistic methods for safety analysis and development of reliability-based design criteria is the assessment of realistic measures of uncertainty underlying the particular technology of design. In every case, careful

and systematic analysis of the major sources of uncertainty in the design process is crucial for developing proper reliability-based design criteria.

The results of this proposed study should form the necessary bases for a better approach to new ship design using the evaluation of realistic probabilities of certain major modes of failure of a ship hull. The availability of this information should then permit the evaluation of the safety of current ships; this may be expressed in terms of the probability of failure on the basis of reasonably prescribed resistance and load probability distributions, or in terms of the "safety index". These latter evaluations can be readily performed once the underlying uncertainties have been assessed and evaluated.

OBJECTIVE

The objective of this study is to identify the major sources of uncertainties underlying the design of ship hull structures.

WORK SCOPE

The following tasks shall be performed to meet the objective:

(1) Examination of current procedures for determining the expected lifetime maximum load on a ship hull to evaluate any bias underlying the current methods of determining design loads relative to the real lifetime maximum load. This shall include a careful assessment

of the coefficient of variation representing the total degree of uncertainty in the predicted lifetime maximum load.

(2) A similar assessment of the bias and uncertainty underlying the current methods for the analysis of stresses and other response quantities of a ship hull.

(3) A systematic examination of the current methods for predicting the resistance of a ship hull to the major modes of failure; for example, the flexural buckling of the main hull girder. The study should be aimed at evaluating any bias in the current methods for calculating the structural resistances in the particular modes being examined, as well as for assessing the coefficients of variation representing the total degree of uncertainty in the predicted resistances of a ship hull.

Available data will invariably be incomplete for the purpose of this study. Nevertheless, efforts should be taken to exhaustively search out all available data, and analyze them for the above purposes. Areas where information is lacking or insufficient shall be supplemented with best judgments; these may have to be expressed or translated into probability terms.

MAN-HOURS

1000

IN-SERVICE STILL-WATER BENDING MOMENT DETERMINATION — SRC Priority 9

Long-Range Goal: Loads Criteria

BACKGROUND

SSC 240, Load Criteria for Ship Structural Design, discusses the determination and the relative importance of:

A. The still-water bending moment (SWBM)

B. The speed-induced wave bending moment

C. Thermal effects

D. Wave Loads

E. Dynamic Loads

All of these have been approached both theoretically and empirically. Advances in computers now makes possible a more sophisticated treatment. In a similar manner, advanced instrumentation and recording equipment open new doors to the collection of data. Developments in both areas, coupled with the introduction of new types of ships and larger ships of old types provide many opportunities for research which should help to achieve eventually the goal of a truly rational method of ship design.

SR-1227, "Load Criteria Application," is a follow-on project to that one reported in SSC 240. It deals with calculation and measurement of load and stress data for three ships - a containership, a bulk carrier and a large tanker. Among the things that were to have been accomplished under SR-1227 was the determination of the

variation in the loads causing still-water bending moments from voyage to voyage and during the course of individual voyages. This proved to be difficult and was not accomplished to the degree desired.

A program is now proposed to develop a plan to obtain service data on SWBM in sufficient quantity to be useful in the formation of a probability-based design method.

OBJECTIVE

The objective of this study is to develop a plan to obtain in-service still-water loading data.

WORK SCOPE

The following tasks are considered essential in developing the program plan:

1. Determine ship types which should be included in the study.
2. Evaluate the relative cost and effectiveness of various methods of obtaining SWBM service data, such as:
   - Keeping loading records on selected ships
   - Recording stresses on selected ships
   - Any other
3. Interview designers, builders, owners, operators and classification societies to determine:
   - Methods they use to control SWBM and their opinion as to their effectiveness

- Their opinion as to the present range of SWBM on the ship with which they are concerned
- The willingness of owners and operators to participate in a research program to record loading conditions and/or to measure stresses via instrumentation.

4. Develop a strategy for recording loads and for calculating SWBM on representative ships. This should contain names of willing ship owners, ship types and names, specific data recording procedure, specific calculational procedure, manning and cost.
5. Develop a similar strategy for obtaining SWBM data by recording stresses on ships throughout the voyage including port time. This should include some or all of the same ships involved in the previous item. A procedure for separating SWBM stresses from other stresses should be established.
6. Determine a specific and detailed program for obtaining still-water loading data, including a cost and time estimate.

MAN-HOURS

1000

DISTORTION IN ALUMINUM WELDMENTS SRC Priority 10

Long-Range Goal: Fabrication Techniques

BACKGROUND

Increased use of aluminum in shipbuilding has emphasized the need for more information on distortion in aluminum structures. The distortion problems in welding aluminum are more severe than those of steel because of the higher coefficient of thermal expansion along with a lower modulus of elasticity. The recent paper by V. J. Papazoglow and K. Masubuchi "Analysis and Control of Distortion in Aluminum Structure" (SNAME Transactions, Vol. 86, 1978) reports on a three-year investigation at M.I.T. directed toward an understanding of the problems and the development of analytical means to predict distortion and analyzing methods of distortion control.

While this work significantly increases available knowledge of distortion in aluminum, most of the attention has been directed to relatively thin plates. Certain types of LNG carriers use welded aluminum structures in heavier thickness ranges where more stringent control of distortion is required.

OBJECTIVE

The objective of this study is to prepare a guide for controlling and accommodating distortion in aluminum weldments throughout the usable thickness range.

WORK SCOPE

The following elements are considered necessary in developing the guide:

1) A review of pertinent domestic and foreign literature.
2) A survey of the design applications of aluminum weldments for various thickness ranges.
3) A documentation of the rationale for controlling and accommodating distortion in aluminum weldments.

MAN-HOURS

1000

LIQUID SLOSH LOADING IN CARGO TANKS SRC Priority 11

Long-Range Goal: Loads Criteria

BACKGROUND

Operation of vessels at sea with partially filled liquid cargo tanks imposes dynamic loadings on the tank boundaries due to movement and sloshing of the tank contents. While the nature and magnitude of these loadings has been studied by many investigators, the information developed by these studies has not been codified and remains scattered in various technical journals. The current Project SR-1251, "Evaluation of Liquid Dynamics in Slack Cargo Tanks" is investigating liquid dynamic loads in slack tanks, but this effort is concentrating rather specifically on LNG in tanks with smooth internal surfaces.

A three-year program is proposed to codify information on dynamic loading of all types of liquid cargoes, tank configurations and fill conditions, with a program of model testing and analysis to fill gaps in available information, and a report format useful to structural designers and ship operators.

OBJECTIVE

The objective of this study is to determine the sloshing loads from a broad selection of liquids of varying properties imposed on tanks of varying proportions with both smooth and structurally stiffened surfaces.

WORK SCOPE

The following tasks are considered essential in establishing sloshing loads:

PHASE I - Literature Search and Parametric Analysis

1. Compile and review available data for prediction of slosh loads based on analysis, model tests or full-scale performance.
2. Correlate data on basis of suitable parameters pertaining to such factors as tank shape and size, interior surface construction and liquid properties such as density and viscosity, and liquid level.
3. Devise a program of model testing and analysis to augment existing information.

PHASE II - Model Testing and Analysis

Implement the program of model testing and/or analysis developed during Phase I.

PHASE III - Codification of Information

Prepare a well organized summary, for use by ship designers and operators, of data on the dynamic loadings of tank boundaries in consideration of ship motions, liquid properties, tank geometries and structural systems, and other pertinent parameters.

MAN-HOURS

First year - Phase I - 1500

Second year- Phase II - 3000

Third year - Phase III - 1500

REVIEW OF ACTIVE AND PENDING PROJECTS

This section of the report covers current projects funded with fiscal 1978 (or earlier) funds, others that have been started with fiscal 1979 funds, and several projects for which proposals are not yet in hand but are anticipated to be supported with fiscal 1979 funds. These projects, listed in Table III, constitute the current program. The majority of projects are for one-year's duration; multiyear projects are funded incrementally on an annual basis.

Project descriptions, including the SR project number and title, the name of the principal investigator and his organization, where these have been determined, and the activation date and funding, where applicable, are provided. The appropriate SSC Long-Range Goal is also noted, and a very brief statement of the objective of each project is given. These are followed by a short description of the present status of the project.

This format does not permit a detailed or comprehensive description of individual projects; however, each project included will normally result in one or more SSC reports.

TABLE III -- REVIEW OF ACTIVE AND PENDING PROJECTS

PROJECT NO:	SR-1238
PROJECT TITLE:	FRACTURE TOUGHNESS CHARACTERIZATION OF SHIP STEEL WELDMENTS
INVESTIGATOR:	Dr. A. K. Shoemaker
CONTRACTOR:	U.S. Steel Corporation, Monroeville, PA
ACTIVATION DATE:	January 28, 1977
CONTRACT FUNDING:	$62,212
SSC LONG-RANGE GOAL:	Materials Criteria

OBJECTIVE

The objective is to determine the relevance of the Charpy V-notch energy criteria currently employed in assessing the behavior of steel weldments.

STATUS

All Charpy, tension, and hardness testing has been completed. Some fatigue-crack initiation tests have been started, but test machine difficulties have intruded into the schedule. Propagation tests and three-point bend full-thickness stress intensity (Kc) tests are now underway. The compressive-fatigue-load range had to be reduced to eliminate the testing machine problems. However, these data can be extrapolated by using the Goodman diagram. A draft final report is scheduled for review in mid-May, 1979.

PROJECT NO:	SR-1241
PROJECT TITLE:	LONGITUDINAL STRENGTH CRITERIA BASED ON STATISTICAL DATA ANALYSIS
INVESTIGATOR:	Mr. N. S. Basar
CONTRACTOR:	M. Rosenblatt & Son, Inc., New York, NY
ACTIVATION DATE:	September 30, 1976
CONTRACT FUNDING:	$16,414
SSC LONG-RANGE GOAL:	Design Methods

OBJECTIVE

The objective of this study is to develop a computer program for a method for analysis of uncertainties associated with ship hull strength due to mill practices, methods of sampling, variations in material properties and scantling sizes, time-dependent effects, etc. with expressions for margins of safety and structural reliability.

STATUS

A draft final report presents the available techniques for probabalistic structural reliability analysis but does not discuss whether the various techniques are practically effective or not. For example, some of the methods mentioned can be complicated while the Monte Carlo method can be very expensive. The final report is being revised to discuss this aspect and to indicate that the determination of an appropriate safety factor for design from probabalistic methods, when used in one of its most effective forms, is most significant. Additional time and funds have been allocated for this revision.

PROJECT NO:	SR-1245
PROJECT TITLE:	REDUCTION OF SL-7 SCRATCH-GAGE DATA
INVESTIGATOR:	Mr. R. F. Brodrick
CONTRACTOR:	Teledyne Engineering Services, Waltham, MA
ACTIVATION DATE:	March 1977
CONTRACT FUNDING:	$88,511
SSC LONG-RANGE GOAL:	Response Criteria

OBJECTIVE

The objective is to obtain and reduce scratch-gage records from eight SL-7 containerships to usable form.

STATUS

Five years of scratch-gage data have been examined, scaled, and presented in the form of histograms. An SSC report will soon be published with these data.

Two additional years of data will be similarly reduced and presented. These data will be augmented with the results of comparisons between the scratch-gage data and the electrical strain gage data obtained aboard the SL-7 SEA-LAND McLEAN. An attempt will also be made to develop transfer functions to correlate those scratch-gage data taken aboard the other seven SL-7 ships.

The additional data collection, formerly obtained under project SR-1215, "SL-7 Extreme Stress Data Collection" is now under SR-1245, to consolidate contracts.

PROJECT NO:	SR-1251
PROJECT TITLE:	EVALUATION OF LIQUID DYNAMIC LOADS IN SLACK LNG CARGO TANKS
INVESTIGATOR:	Dr. R.L. Bass
CONTRACTOR:	Southwest Research Institute, San Antonio, TX
ACTIVATION DATE:	September 16, 1977
CONTRACT FUNDING:	$72,159
SSC LONG-RANGE GOAL:	Loads Criteria

OBJECTIVE

The objective of this study is to survey, test, analyze, and develop liquid dynamic load criteria in slack LNG cargo tanks.

STATUS

A search of the open literature produced little useful information on the structural analysis for sloshing pressures, but did provide sufficient model data to cover a wide range of fill depths, excitation frequencies, and amplitudes, tank-wall pressures measurement locations, and total force measurements. Model test results conducted in this project using two degrees of simultaneous excitation indicate that worst case situations occurred when the heaving and surging excitation frequencies were equal and set at the resonant frequency for surging only motion. Additional preliminary results indicate that the experimental and theoretical resonant period agree well for the pitching, surging, and combined surging and heaving excitation motions.

PROJECT NO:	SR-1254
PROJECT TITLE:	FATIGUE CONSIDERATIONS IN VIEW OF MEASURED LOAD SPECTRA
INVESTIGATOR:	Mr. R.F. Brodrick
CONTRACTOR:	Teledyne Engineering Services, Waltham, MA
ACTIVATION DATE:	June 21, 1978
CONTRACT FUNDING:	$58,582
SSC LONG-RANGE GOAL:	Materials Criteria

OBJECTIVE

The objective of this study is to assess the influence of fatigue loading spectra on the margin of safety provided by current fatigue design practices.

STATUS

A literature survey of ship loads and fatigue behavior has been completed. Preliminary analysis of the bulk carrier FOTINI L data indicates it may be possible to define a fatigue load spectrum in terms of peak stress distributions, mean stress, area under the spectral density curve, characteristic period, and encounter cycles. Crack-growth retardation models are being examined by using ship loading spectra as input.

PROJECT NO:	SR-1255
PROJECT TITLE:	NONDESTRUCTIVE INSPECTION OF HEAVY SECTION CASTINGS, FORGINGS, AND WELDMENTS
INVESTIGATOR:	Mr. E.L. Criscuolo
CONTRACTOR:	Naval Surface Weapons Center, White Oak, MD
ACTIVATION DATE:	June 1, 1977
CONTRACT FUNDING:	$20,000
SSC LONG-RANGE GOAL:	Fabrication Techniques

OBJECTIVE

The objective of this study is to survey representative nondestructive inspection methods for ship castings, forgings, and weldments, and identify existing acceptance standards.

STATUS

Specifications regarding procedure and suggested acceptance criteria were obtained for both the ultrasonic and radiographic methods of nondestructively inspecting large steel castings.

In addition, ASTM procedural guides have been reviewed for suitability to this application.

These data are being incorporated into a technical report.

PROJECT NO:	SR-1256
PROJECT TITLE:	INVESTIGATION OF STEELS FOR IMPROVED WELDABILITY IN SHIP CONSTRUCTION
INVESTIGATOR:	Mr. R.W. Vanderbeck
CONTRACTOR:	U.S. Steel Corporation, Monroeville, PA
ACTIVATION DATE:	September 29, 1978
CONTRACT FUNDING:	$204,796
SSC LONG-RANGE GOAL:	Fabrication Techniques

OBJECTIVE

The objective of this three-year study is to select the optimum materials and welding parameters to provide improved resistance to degradation of the heat-affected-zone (HAZ) properties in weldments made with high-deposition rate processes.

STATUS

A literature survey is underway to serve as a basis for the selection of promising experimental steels that will be produced as laboratory heats. The best of these steels will be screened out by simulated HAZ testing, and, along with two reference production ship-plate-type heats, will be evaluated by various tests on base metal and weld HAZ (various heat inputs). The metallurgical factors contributing to improved HAZ behavior will be identified. Finally, the most promising steel will be commercially produced and evaluated using several welding processes and a variety of tests including Charpy V-notch in various locations in the weld HAZ.

PROJECT NO:	SR-1257
PROJECT TITLE:	FATIGUE CHARACTERIZATION OF FABRICATED SHIP DETAILS
INVESTIGATOR:	Prof. W.H. Munse
CONTRACTOR:	University of Illinois, Urbana, IL
ACTIVATION DATE:	November 30, 1978
CONTRACT FUNDING:	$95,016
SSC LONG-RANGE GOAL:	Materials Criteria

OBJECTIVE

The objective of this two-year study is to classify ship details in terms of their behavior and useful life under cyclic-loading conditions.

STATUS

Work has begun on a literature survey, evaluation of current fatigue criteria, and classification of fabricated ship details.

These phases are to follow:

a) Identification of details for which fatigue data are plentiful, limited, or lacking.

b) Development of fatigue design criteria, and

c) Laboratory fatigue tests to verify the classification procedure and to supply missing data.

PROJECT NO:	SR-1258
PROJECT TITLE:	STRUCTURAL DETAILS FAILURE SURVEY CONTINUATION
INVESTIGATOR:	Mr. C.R. Jordan
CONTRACTOR:	Newport News Dry Dock and Shipping Company, Newport News, VA
ACTIVATION DATE:	December 6, 1977
CONTRACT FUNDING:	$49,761
SSC LONG-RANGE GOAL:	Fabrication Techniques

OBJECTIVE

The objective of this study is to evaluate the effectiveness of structural details by examining several details in selected ships undergoing repairs or periodic surveys.

STATUS

Surveys have been made on 5 bulk carriers, 11 general cargo ships, and 12 containerships, concentrating on the midship cargo sections, to augment the data obtained in Project SR-1232, "Structural Details Failure Survey."

PROJECT NO:	SR-1259
PROJECT TITLE:	A LONG-RANGE RESEARCH PROGRAM IN SHIP STRUCTURES
INVESTIGATOR:	Mr. R.J. Scott
CONTRACTOR:	Gibbs & Cox, Inc., Arlington, VA
ACTIVATION DATE:	January 31, 1979
CONTRACT FUNDING:	$213,740
SSC LONG-RANGE GOAL:	Advanced Concepts and Long-Range Planning

OBJECTIVE

The objective of this two-year study is to develop a marine structures planning document directed toward, but not limited to, the technical goals and charter of the Ship Structure Committee, and to forecast the research and development needs, based on a system of priorities, for the next 20 years.

STATUS

A format is being developed to assess the cost reduction, safety, environmental, and military effectiveness benefits of candidate long-range research plans. Subsequently, a quantitative measure of these benefits per research and development dollar invested will be proposed. Simultaneously, workshop conferences will be conducted to identify the structural problems that need to be addressed. Finally, a final planning document will be prepared that will include background material, a summary of the technical approaches and method formulation, the benefits and the technical man-hour estimates for the recommended programs.

PROJECT NO:	SR-1261
PROJECT TITLE:	HULL STRUCTURAL DAMPING DATA
INVESTIGATOR:	Mr. T.P. Carroll
CONTRACTOR:	Carroll Associates, Bethesda, MD
ACTIVATION DATE:	February 1979
CONTRACT FUNDING:	$21,733
SSC LONG-RANGE GOAL:	Design Methods

OBJECTIVE

The objective of this study is to collect and evaluate structural damping data applicable to ship vibration analysis, and to recommend an experimental program, model or full scale, to expand and verify the design data.

STATUS

This project is getting underway after some delay incident to clarifying the contractor's proposed work statement and insuring the participation of an expert hydrodynamicist.

PROJECT NO: SR-1262
PROJECT TITLE: ULTIMATE STRENGTH OF SHIP HULL GIRDER
INVESTIGATOR: Dr. A.E. Mansour
CONTRACTOR: Mansour Engineering, Inc., Berkeley, CA
ACTIVATION DATE: May 1, 1978
CONTRACT FUNDING: $37,080
SSC LONG-RANGE GOAL: Design Methods

OBJECTIVE

The objective of this study is to develop a procedure to determine the load-deformation characteristics and ultimate strength of a ship hull girder under various combinations of vertical, lateral, and torsional loads.

STATUS

An interaction relation has been established that allows for the determination of the reduction in either the fully plastic vertical, lateral, or torsional moment under various magnitudes and combinations of the other two moments. Applications of several of the developed relations to a 190,000 DWT ship and a 930 ft. barge have been made. Other types of ships, buckling, strain hardening effects, rationale for combining maximum shear and bending moment values from different shipboard locations, relation of procedures to experimental data still remain to be examined.

PROJECT NO:	SR-1263
PROJECT TITLE:	SHIP STRUCTURAL DESIGN CONCEPTS - PART II
INVESTIGATOR:	Dr. J.H. Evans
CONTRACTOR:	J.H. Evans, Lexington, MA
ACTIVATION DATE:	March 1, 1978
CONTRACT FUNDING:	$25,000
SSC LONG-RANGE GOAL:	Design Methods

OBJECTIVE

The objective of this two-year study is to prepare a supplementary monograph to the Ship Structural Design Concepts published in 1974.

STATUS

A suggested title for this monograph is "Other Topics on Ship Structural Design" and will now embrace the following nine chapter headings: 1) Hull Deckhouse Interactions," (2) Shearing Stresses Due to Bending, 3) Shearing Stresses Due to Torsion, 4) Principal Stresses, 5) Extent of Unreduced Scantlings, 6) Hull Girder Deflections and Stiffness, 7) Full-Scale Longitudinal Strength Experiments, 8) Hull Cross-Section Synthesis in the Presence of Bending Plus Shear, and 9) Preliminary Choice of Framing Systems.

A number of chapters have been completed and others are in the draft stage.

PROJECT NO:	SR-1265
PROJECT TITLE:	EVALUATION OF FRACTURE CRITERIA FOR SHIP STEELS AND WELDMENTS
INVESTIGATOR:	Prof. A.W. Pense
CONTRACTOR:	Prof. A.W. Pense, Bethlehem, PA
ACTIVATION DATE:	April 4, 1978
CONTRACT FUNDING:	$6,800 from American Iron and Steel Institute
SSC LONG-RANGE GOAL:	Materials Criteria

OBJECTIVE

The objective of this study is to prepare a state-of-the-art interpretative report on the correlation of fracture toughness in ship steels and weldments to proposed criteria for adequate resistance to fracture in service.

STATUS

A report outline has been reviewed and data are being gathered and analyzed. Answers to the following questions are being sought:

1. Are enough data available to adequately assess the proposed fracture-toughness criteria?
2. Are the proposed fracture-test methods adequate measures of material performance in ship applications?
3. Based on material data and service performance, are modifications to the proposed criteria needed?

PROJECT NO:	SR-1266
PROJECT TITLE:	CRITERIA FOR HULL/MACHINERY RIGIDITY COMPATIBILITY
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	2000 man-hours
SSC LONG-RANGE GOAL:	Response Criteria

OBJECTIVE

The objective of this study is to develop criteria for compatability in rigidity of hull and main-propulsion machinery.

STATUS

Proposals have been evaluated.

PROJECT NO: SR-1267
PROJECT TITLE: ICR STRENGTHENING CRITERIA FOR SHIPS
INVESTIGATOR: Unknown
CONTRACTOR: Unknown
ACTIVATION DATE: Unknown
CONTRACT FUNDING: 2000 man-hours
SSC LONG-RANGE GOAL: Loads Criteria

OBJECTIVE

The objective of this study is to develop a basis for a rational selection of ice strengthening criteria for vessels.

STATUS

Proposals have been evaluated.

PROJECT NO:	SR-1268
PROJECT TITLE:	EVALUATION OF SL-7 SCRATCH-GAGE DATA
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	800 man-hours
SSC LONG-RANGE GOAL:	Response Criteria

OBJECTIVE

The objective of this study is to establish a measure for judging when sufficient scratch-gage data have been obtained so that the gages can be removed for placement aboard other ships.

STATUS

A proposal request has been prepared.

PROJECT NO: SR-1269
PROJECT TITLE: INTERNAL CORROSION AND CORROSION CONTROL ALTERNATIVES
INVESTIGATOR: Unknown
CONTRACTOR: Unknown
ACTIVATION DATE: Unknown
CONTRACT FUNDING: 2000 man-hours
SSC LONG-RANGE GOAL: Materials Criteria

OBJECTIVE

The objective of this project is to develop a method for making sensitivity studies of the relative life-cycle costs of corrosion control techniques, including combinations of increased scantlings, full or partial coatings, and anodes, to protect internal surfaces of ballast and cargo tanks in steel tankers.

STATUS

A request for proposals has been issued.

PROJECT NO: SR-1270
PROJECT TITLE: SURVEY OF EXPERIENCE USING REINFORCED CONCRETE IN FLOATING MARINE STRUCTURES
INVESTIGATOR: Unknown
CONTRACTOR: Unknown
ACTIVATION DATE: Unknown
CONTRACT FUNDING: 1000 Man-hours
SSC LONG-RANGE GOAL: Advanced Concepts and Long-Range Planning

OBJECTIVE

The objective of this project is to assess the state-of-the-art for reinforced concrete, including prestressed and conventionally reinforced concrete, applicable to floating marine structures.

STATUS

A request for proposals has been issued.

PROJECT NO:	SR-1271
PROJECT TITLE:	PRESSURE DISTRIBUTION MODEL TESTS IN WAVES
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	2400 Man-hours
SSC LONG-RANGE GOAL:	Response Criteria

OBJECTIVE

The objective of the project is to measure model-test hull surface pressures and compare them with calculated pressures.

STATUS

Proposals have been evaluated.

PROJECT NO:	SR-1272
PROJECT TITLE:	COMPUTER-AIDED PROCEDURE FOR SHIP GROUNDING CALCULATIONS
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	2000 Man-hours
SSC LONG-RANGE GOAL:	Advanced Concepts and Long-Range Planning

OBJECTIVE

The objective of this project is to develop a general purpose computer program for ship grounding analysis.

STATUS

A revised prospectus has been prepared.

PROJECT NO:	SR-1273
PROJECT TITLE:	COMPUTER-AIDED PROCEDURE FOR DRYDOCKING CALCULATIONS
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	2000 Man-hours
SSC LONG-RANGE GOAL:	Design Methods

OBJECTIVE

The objective of the project is to develop a computer program to calculate individual drydock block loads, primary hull-bending loads upon drydocking and the stresses in the pontoon deck of the floating drydock.

STATUS

A revised prospectus has been prepared.

PROJECT NO:	SR-1274
PROJECT TITLE:	COMPUTER-AIDED, PRELIMINARY SHIP STRUCTURAL DESIGN
INVESTIGATOR:	Unknown
CONTRACTOR:	Unknown
ACTIVATION DATE:	Unknown
CONTRACT FUNDING:	500 Man-hours
SSC LONG-RANGE GOAL:	Design Methods

OBJECTIVE

The objective of this project is to assess the state-of-the-art of computer-aided design systems in both ship and non-ship areas for use in preliminary ship structural design.

STATUS

A request for proposals has been issued.

PROJECT NO:	SR-1275
PROJECT TITLE:	FULL-SCALE PRESSURE DISTRIBUTION MEASUREMENTS OF M/V S.J. CORT
INVESTIGATOR:	Mr. A.L. Dinsenbacher
CONTRACTOR:	David Taylor Naval Ship Research and Development Center, Carderock, MD
ACTIVATION DATE:	December 19, 1978
CONTRACT FUNDING:	$63,500
SSC LONG-RANGE GOAL:	Response Criteria

OBJECTIVE

The objective is to measure full-scale pressure distributions for use in validating pressure prediction analysis methods.

STATUS

Fifteen inserts have been installed in the forward quarter length of the M/V S.J. CORT's hull plating. Arrangements are being negotiated to obtain, install and calibrate pressure gages and signal conditioning units developed from a prior SSC full-scale slamming instrumentation project.

NOTES

REVIEW OF COMPLETED PROJECTS

The projects completed since the last annual report are listed below. Project descriptions, similar to those for the active program, follow. Reports from these projects have either been published or are presently in the publication process and the final SSC reports can be expected in the near future.

PROJECT NO: SR-1215
PROJECT TITLE: SL-7 EXTREME STRESS DATA COLLECTION
INVESTIGATOR: Mr. R. Boentgen
CONTRACTOR: Teledyne Engineering Services, Waltham, MA
ACTIVATION DATE: September 27, 1972
CONTRACT FUNDING: $102,495
SSC LONG-RANGE GOAL: Response Criteria

OBJECTIVE

The objective of this study is to instrument eight SL-7 containerships with inexpensive, mechanical strain gages, for a period of years.

RESULTS

Records have been continuously collected from eight SL-7 containerships through their fifth year of operations. These records have been reduced under project SR-1245, "Reduction of SL-7 Scratch Gage Data."

An additional two years of records are being collected and reduced in project SR-1245. Therefore, project SR-1215 is being retired.

PROJECT NO:	SR-1222
PROJECT TITLE:	MATERIALS TRADE-OFF STUDY
INVESTIGATOR:	Mr. C. K. Jordan
CONTRACTOR:	Newport News Shipbuilding & Dry Dock Company, Newport News, VA
ACTIVATION DATE:	May 9, 1977
CONTRACT FUNDING:	$46,114
SSC LONG-RANGE GOAL:	Advanced Concepts and Long-Range Planning

OBJECTIVE

The objective of this study was to examine the potential for the application of modern unconventional materials to advanced ship types, unique operations, and special capabilities.

RESULTS

A method for evaluating the desirability of any proposed material in merchant ship structure has been developed. This method compares a ship designed using the new material with a similar steel ship. Comparison includes a life-cycle cost analysis and a quantified evaluation of non-economic factors. Formalized techniques for establishing the material data bank, selecting the steel ship design, developing and optimizing the new material design, and conducting the economic and non-economic comparisons are described. A sample calculation, using 5456 aluminum in a bulk ore carrier, is included to illustrate the method.

PROJECT NO: SR-1227
PROJECT TITLE: LOAD CRITERIA APPLICATION
INVESTIGATOR: Mr. N.M. Maniar
CONTRACTOR: M. Rosenblatt & Son, Inc., New York, NY
ACTIVATION DATE: April 19, 1975
CONTRACT FUNDING: $60,340
SSC LONG-RANGE GOAL: Loads Criteria

OBJECTIVE

The objective was to conduct a study of statistically based load predictions of a containership, a large tanker, and a dry-bulk carrier for which actual stress records and service repair histories are available and to compare the results with the prediction methods presented in SSC-240, Load Criteria for Ship Structural Design.

RESULTS

Considerable insight is obtained into the probable correct mathematical approximations of the loads and their inter-relationships among the following bending moments:

- Still-water due to weight and buoyancy
- Ship's own wave train
- Quasi-static wave-induced, vertical and lateral combined
- Dynamic loads, including slamming, whipping, and springing
- Thermal effects

It appears that still-water bending moments can be approached probabilistically. However, additional information on experienced loading conditions must be gathered to determine the statistical distributions. More effort is also required to determine the suitable probabilistic expression and a synthesis method for the contribution of vibration to the extreme loads.

PROJECT NO: SR-1236
PROJECT TITLE: SL-7 STRESS CALCULATIONS COMPARED WITH FULL-SCALE MEASURED VALUES
INVESTIGATOR: Dr. H. Y. Jan
CONTRACTOR: American Bureau of Shipping, New York, NY
ACTIVATION DATE: December 9, 1976
CONTRACT FUNDING: SSC-$81,033; ABS-$150,491
SSC LONG-RANGE GOAL: Response Criteria

OBJECTIVE

The objective of the study was to compare calculated stresses to those measured on the SL-7 in corresponding sea and load conditions and to evaluate the results through each of four different and progressively more severe technical conditions.

RESULTS

The overall comparison between calculated and measured stresses for the dockside calibration is good where thermal effects were small but inconclusive otherwise. The comparison of RMS stresses in head seas is generally satisfactory, using both the spectrum analysis approach and the equivalent regular wave approach, and the comparison of instantaneous stresses in head seas and in oblique seas is also good for the wave conditions considered.

The results show that the existing analytical tools for predicting wave loads and structural responses are suitable to assess the overall strength of the hull-girder. All the measured and calculated hull-girder stresses are of low magnitude, and no modifications to the present hull-girder strength standard are deemed necessary.

PROJECT NO: SR-1237
PROJECT TITLE: CRITICAL EVALUATION OF LOW-ENERGY COLLISION DAMAGE THEORIES AND DESIGN METHODOLOGIES
INVESTIGATOR: Dr. Paul Van Mater, Jr.
CONTRACTOR: Giannotti & Buck Associates, Inc., Annapolis, MD
ACTIVATION DATE: February 28, 1977
CONTRACT FUNDING: $33,879
SSC LONG-RANGE GOAL: Advanced Concepts and Long-Range Planning

OBJECTIVE

The objective was to make recommendations for the use of current methods of structural analysis in the development of low-energy collision damage theories and design methodologies and to point out the limits to their use by a critical evaluation of present practice in applicable structural analyses.

RESULTS

There are three methods to follow to make a structural analysis of collision damage. These are: (1) the Rosenblatt method, (2) extension of Minorsky's high-energy method into the low-energy range, and (3) the finite-element method. The Rosenblatt method is available now and would be the least expensive approach to follow. The finite-element method approaches the ideal solution but at too high a price for use in ship design practice. The extension of Minorsky's method to the low-energy range could well be the compromise because it circumvents some of the limitations of the Rosenblatt method and at a relatively low cost by comparison with the finite-element method.

PROJECT NO: SR-1229
PROJECT TITLE: RATIONAL LIMIT OF HULL FLEXIBILITY
INVESTIGATOR: Dr. P. Y. Chang
CONTRACTOR: Hydronautics, Inc., Laurel, MD
ACTIVATION DATE: March 31, 1977
CONTRACT FUNDING: $54,500
SSC LONG-RANGE GOAL: Design Methods

OBJECTIVE

The objective of this study was to evaluate the effect that varying ship proportions and hull materials would have on hull flexibility and on the concomitant bending and vibratory stresses.

RESULTS

With the flexibility of the ship's hull represented by the natural frequency of the ship associated with the two-node shape, a potentially useful relation between the flexibility and bending moment has been established.

An analysis indicates that forward speed has effects on hydrodynamic damping and forces as well as hull flexibility.

A more accurate method for ship vibration analysis is required and can be developed within the state-of-the-art of the current theories of hydrodynamics and structural mechanics.

From the results obtained in this study, there may exist an optimal flexibility for every ship, but there is not necessarily a limit to the flexibility.

PROJECT NO: SR-1240
PROJECT TITLE: PROPELLER-INDUCED VIBRATION IN HULL STRUCTURAL ELEMENTS
INVESTIGATOR: Dr. D.D. Kana
CONTRACTOR: Southwest Research Institute, San Antonio, TX
ACTIVATION DATE: February 4, 1977
CONTRACT FUNDING: $60,370
SSC LONG-RANGE GOAL: Loads Criteria

OBJECTIVE

The objective of this study was to recommend design procedures intended to avoid vibration problems for such structural elements as stiffened and unstiffened plate panels, deep web supporting decks, bulkheads, and the hull shell.

RESULTS

A 27-step general method of ship design to minimize propeller-induced vibrations for any ship design has been defined in six design phases: 1) Specifications, 2) Preliminary Hydrodynamics, 3) Final Hydrodynamics, 4) Ship Substructure, 5) Complete Ship Structure, and 6) Test and Evaluation However, certain areas require further work to:

a. Establish the relationships of the ship's stern form to the wake and its variations, and the wake and wake variations to the propeller forces, hull pressure forces, and propeller cavitation.
b. Understand the effects of a working propeller on the nominal wake distribution.
c. Refine analytical methods to predict hull pressures caused by cavitation.
d. Establish guidelines for the acceptability of propeller-generated forces and pressures based upon gross ship properties.
e. Improve prediction techniques for both the propeller-generated forces and the response of the rudder.

PROJECT NO: SR-1243
PROJECT TITLE: UNDERWATER NONDESTRUCTIVE INSPECTION OF WELDS
INVESTIGATOR: Mr. C.H. Dyer
CONTRACTOR: Naval Surface Weapons Center, White Oak, MD
ACTIVATION DATE: December 15, 1976
CONTRACT FUNDING: $41,000
SSC LONG-RANGE GOAL: Fabrication Techniques

OBJECTIVE

The objective of this study was to propose modifications to existing methods of nondestructive weld inspection to adapt them to underwater use.

RESULTS

Nondestructive weld inspection can be done underwater. Existing equipment must be modified for underwater application. These modifications are feasible, and in fact, have been done, but may not yet be available commercially.

No underwater method has been found which obviates the need for a diver.

PROJECT NO: SR-1246
PROJECT TITLE: SURVEILLANCE OF SHIP COLLISION/STRANDING RESEARCH STUDIES
INVESTIGATOR: Prof. N. Jones
CONTRACTOR: Massachusetts Institute of Technology, Cambridge, MA
ACTIVATION DATE: July 21, 1977
CONTRACT FUNDING: $12,934
SSC LONG-RANGE GOAL: Advanced Concepts and Long-Range Planning

OBJECTIVE

The objective of this study was to identify and monitor past and current collision or stranding research and to issue status reports that will include concise discussion of new reports and new programs on related research projects.

RESULTS

A large number of articles have been published on various aspects of the structural strength of ships during collisions but very few appear on the ship grounding problem. Little experimental data are available to reveal various features of the buckling and post-buckling behavior, constitutive equations, stress rate effects, and fracture mechanisms in collisions. An exact numerical solution of the actual ship collision problem is not now possible. Approximate methods idealize the structures as a collection of simple components with a known structural response. The methods examined are too time-consuming and expensive for preliminary design, but would probably be more suitable for the final design stage.

PROJECT NO: SR-1248
PROJECT TITLE: UPDATING OF FILLET WELD STRENGTH PARAMETERS FOR SHIPBUILDING
INVESTIGATOR: Prof. K. Masubuchi
CONTRACTOR: Massachusetts Institute of Technology, Cambridge, MA
ACTIVATION DATE: July 11, 1977
CONTRACT FUNDING: $30,609
SSC LONG-RANGE GOAL: Fabrication Techniques

OBJECTIVE

The objective of this study was to recommend updated fillet weld requirements for domestic ship application by reviewing the development of current marine fillet weld requirements and available test data.

RESULTS

The review of how fillet weld requirements were developed was unproductive. Comparisons among fillet weld size requirements of various classification societies and regulatory bodies revealed a variation as large as a factor of two. An existing finite element computer program was modified to analyze the behavior of fillet welds. Variations in fillet weld size and root gap were examined under a simple load condition to demonstrate the method. Future work should include application of this type of analysis to various structural joint details characterized by location in the ship, type and function of members joined and nature of loading. Comparison with existing requirements will indicate the feasibility or not of reducing fillet weld sizes.

PROJECT NO: SR-1249
PROJECT TITLE: RADIOGRAPHY GUIDELINES FOR SECONDAPY MEMBERS
INVESTIGATOR: Mr. E.L. Criscuolo
CONTRACTOR: Naval Surface Weapons Center, White Oak, MD
ACTIVATION DATE: December 16, 1976
CONTRACT FUNDING: $31,000
SSC LONG-RANGE GOAL: Fabrication Techniques

OBJECTIVE

The objective of the study was to determine whether additional inspection guidelines are needed after ship building structural welds of webs and longitudinals have been surveyed.

RESULTS

After an extensive search of ship casualty reports, a review of available radiographs, a survey of major shipyards, and discussions with prominent naval architects, it was determined that no additional weld inspection guidelines for a ship's webs and longitudinals are needed.

PROJECT NO: SR-1250
PROJECT TITLE: SIGNIFICANCE AND CONTROL OF LAMELLAR TEARING OF STEEL PLATE IN THE SHIP-BUILDING INDUSTRY
INVESTIGATOR: Mr. John Sommella
CONTRACTOR: Gibbs & Cox, New York, NY
ACTIVATION DATE: November 11, 1977
CONTRACT FUNDING: $11,154
SSC LONG-RANGE GOAL: Fabrication Techniques

OBJECTIVE

The objective of this study was to prepare a document containing reasonable guidelines, welding procedures, and testing methods to prevent lamellar tearing in ship structures using steels up to 100 ksi yield strength

RESULTS

The document has been prepared, reviewed, and is awaiting approvals to use some copyrighted material. The report contains the following sections:

1. Introduction
2. Description of Lamellar Tearing
3. Factors Contributing to Lamellar Tearing
4. Occurrence of Lamellar Tearing
5. Significance of Lamellar Tearing
6. Control of Lamellar Tearing
7. Detection and Repair of Lamellar Tearing after Welding
8. Tests for Determining the Susceptibility of Steel Plates to Lamellar Tearing
9. Bibliography

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.96	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in. = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
MASS (weight)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

Technical Report Documentation Page

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16 Abstract

The Ship Research Committee (SRC) of the National Research Council provides technical services covering program recommendations, proposal evaluations and project advice to the interagency Ship Structure Committee (SSC), composed of representatives from the U.S. Coast Guard, the Naval Sea Systems Command, the Military Sealift Command, the Maritime Administration, the American Bureau of Shipping and the U.S. Geological Survey. This arrangement requires continuing interaction among the SRC, the SSC, the contracting agency and the project investigators to assure an effective program to improve ship hull structures through an extension of knowledge of materials, fabrication methods, static and dynamic loading and response, and methods of analysis and design. This report contains the Ship Research Committee's recommended research program for five years, FY 1979 - 1983, with 11 specific prospectuses from which to select projects for FY 1980. Also included is a brief review of 24 active and 12 recently completed projects.

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